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Effects of SOIL FERTILITY LEVELS on the quality of Fresh and Processed TOMATOES SWEET CORN CABBAGE

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THE EFFECTS OF SOIL FERTILITY LEVELS ON THE QUALITY OF FRESH AND PROCESSED TOMATOES, SWEET CORN, AND CABBAGE

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INTRODUCTION

A series of tests (1, 2, 3 and 7) carried on with controlled fertility levels in water and sand cultures in greenhouses proved that significantly lower carotene values were obtained from chard plants receiving insufficient nitrogen, magnesium and iron and that significantly higher ascorbic acid values were obtained from chard plants deficient in nitrogen, magnesium, manganese, and potassium. Ascorbic acid contents obtained from plants grown in plots to which double the amount considered adequate of the element in question was added, were significantly lower in the case of double-nitrogen, double-potassium, and double-phosphorus plots. The data indicated similar trends for other leafy vegetables. The amount of carotene in tomato fruits and beet roots, were decreased appreciably due to deficiencies of both boron and manganese.

Upon the completion of these studies a similar study was made using tomatoes grown in the Experiment Station greenhouses at Wooster, and cabbage and sweet corn grown in the open plots of varying fertility at Marietta. These latter studies were expanded to include the effects of fertility levels upon the canned as well as the fresh products. Accepted commercial practices were followed in growing the greenhouse and outdoor crops.

GREENHOUSE SOIL EXPERIMENTAL PROCEDURES

An impoverished Wooster silt loam was selected for the basic soil in the greenhouses at Wooster. It was known to supply inadequate amounts of phosphorus and nitrogen for average yields of tomatoes. Furthermore, the potassium supply was known to be low so that it limited tomato yields after harvest of several crops following the additions of supplementary nitrogen and phosphorus.

[1]Portions of the material included herein were used for theses submitted as partial fulfillment of M. S. degrees.

To further insure different levels of nitrogen, phosphorus and potassium the following amounts of the fertilizers indicated were applied in terms of pounds per acre: to the nitrogen series 0 (minus N); 25 (low N); 75 (medium N); 225 (high N); and 675 (very high N) pounds of 35 percent ammonium nitrate applied five times, i. e., once before the fall crop was planted and once before the spring crop was planted, twice during the growth of the spring crop and once during the growth of the fall crop. To the phosphorus series, 0 (minus P); 500 (low P); 1000 (medium P); 2000 (high P) and 4000 (very high P) of 20 percent superphosphate applied once before the spring and once before the fall crop. The potassium series 0 (minus K); 375 (low K); 750 (medium K); 1000 (average amount of K); 1500 (high K); and 3000 (very high K) of 50 percent sulphate of potash applied before the spring crop and before the fall crop. The soil in the minus NPK plot received no fertilizer. The high applications of each fertilizing material were effective in preventing the appearance of their respective starvation symptoms.

OUTDOOR SOIL

The soils in the fertility plots at Marietta have been classified as Chenango loam to a Chenango fine sandy loam. The fertility treatments and results have been presented in Station Bulletins 377, 420, 622 and 697. The fertilizer treatments applied to the plots used to grow vegetables for this research are presented in Table 1. The yields of cabbage, tomatoes and sweet corn for the 1949 season are given in Table 2. It is obvious that the fertilizer treatments which were started in 1947 had to a large extent eliminated the yield reductions which were apparent in 1945 and 1946 (for details see Bulletin No. 697) as a result of fifteen years (1931-46) of treatments as shown in Table 1. Unfortunately the data in Table 2 were not available when the crops were harvested in 1948 and 1949. This made it necessary to rely on previous data and field observations, in selecting plots which appeared to provide the desired material. It was deemed advisable to select different plots in 1948 than in 1949 to represent different fertility levels.

The Nitrogen Series.—Plots 6, 3 and 35 were selected as the low, medium, and high nitrogen series in 1948 and plots 6, 27, 5 and 2 were selected as the very low, low, medium and high nitrogen series in 1949. It is felt that these selections were justified on the basis of the fertility treatments and the type of growth. The data in Table 2 tend to confirm the wisdom of these selections.

Phosphorus Series.—Plots 31 and 23, respectively, were selected as the low and high phosphorous series in 1948 and Plot 29 as the low and Plot 34 as the high phosphorous plots in 1949. It was assumed by

TABLE 1.—Amounts of Fertilizer Constituents Applied to the Soil in the Marietta Plots, and Data of Soil Tests

Plot	Average annual application of phosphoric acid per acre, lb.		Available P per acre shown by test, lb.			Average annual application of potash per acre, lb.		Available K per acre shown by Ohio test, lb.	
			Truog test	Ohio test					
	1915-46	1947-49	1946	1946	1950	1915-46	1947-48	1946	1950
6 no N	154*	40	390	690	850	85*	120	580	640
5 low N (40 lb.)	108*	40	370	450	760	160*	120	728	704
27 low (16 T. manure)	64*	64*	278	335	350	160*	160*	548	730
3 med. N (80 lb.)	88*	40	335	390	470	120*	120	660	680
9 high N (120 lb.)	108	40	373	450	590	80	160	550	620
23 N from manure	200*	32*	730	1000	840	120*	80*	600	550
Beginning 1947, the following plots all received 40 pounds of N per acre in initial fertilizer and two side dressings of 40 lb. each.									
31 low P	32	80	74	148	170	52	120	345	430
32 med. P	60	40	159	195	200	40	120	295	400
29 med. P	60	40	199	295	330	40	120	450	475
34 high P	132	0	380	595	490	40	120	420	345
11 low K	108	40	293	545	550	0	40	140	140
12 med. K	60	40	249	480	380	40	80	260	230
35 med. K	60	40	264	335	310	40	120	368	376
9 high K	108	40	373	450	590	80	160	550	620
2 high P and K	136*	40	580	595	760	120*	120	700	700

*Part or all of the fertility supplied by manure, estimated to have contained 4 pounds of phosphoric acid and 10 pounds of potash per ton. In some of the following tables, manured plot 23 is also listed in the P series as a plot with very high P.

TABLE 2.—Yield of Crops in Fertilizer Experiment at Marietta

Plot	Marketable Produce, Pounds Per Acre			
	Cabbage		Sweet Corn	
	1948	1949	1948	1949
6 No N	26440	16220	4540	12496
5 Low N	43240	40780	6800	13120
3 Medium N	44920	39040	6660	14120
9 High N	45040	45440	6452	13600
23 N from manure	30800	22640	5960	13240
31 Low P	38400	39380	4560	11952
32 Medium P	39800	38780	7320	12000
29 Medium P	40440	40060	7360	13060
34 High P	38680	42660	6160	12420
11 Low K	36920	35040	4320	11020
12 Medium K	44440	39960	5212	13080
35 Medium K	38600	38780	5600	12000
9 High K	45040	45440	6452	13600
2 High P and K	41720	38520	5880	12840

Bushnell (5) that 200 pounds per acre of phosphorus, as determined by the Troug method was the threshold for maximum yields of potatoes and tomatoes. Plot 31 which had only 74 pounds of available phosphorus per acre in 1946 would not have had more than 144 pounds (74+35+35) of phosphorus in 1948. Plot 29 selected as the low phosphorus plot in 1949 was a questionable choice in the light of the data shown in Table 1. Plots 23 and 34 were obviously high in phosphorus and Plot 23 could have been considered as being very high in phosphorus even after two (2) years of cropping (i. e. after 1946) without any additions of phosphorus. It is thus evident that the selections which were made prior to the time the data in Tables 1 and 2 were made available were actually representative of low and high levels of phosphorus with one possible exception (i. e. Plot 29).

Potassium Series.—A critical examination of the data in Tables 1 and 2 indicate that the selection of Plots 11, 12 and 9 as the low, medium and high levels of potassium of 1948 and 1949 are probably justifiable. Subsequent analysis of these soils for available potassium confirmed these selections.

VARIETIES USED

Strain A Globe tomatoes grown in the greenhouses at Wooster were used both years. The fruits were allowed to ripen on the vine as for canning and harvested weekly. The lots usually consisted of 8 to 10 fruits. In most instances the fruit was allowed to ripen for approximately two days in the laboratory (temperature approximately 72° F.) before processing.

Golden Acre cabbage grown as a spring crop at Marietta was used both years. It is not usually made into kraut but the heads were allowed to become very solid before harvesting in order to insure a maximum of carbohydrate content at that season of the year. Approximately 50 pounds per lot was harvested at about 2 p. m., brought to the laboratories at Columbus and stored over night at room temperature (about 75° F.) before processing.

Marcross sweet corn was used in 1948 and Golden Security in 1949. Each lot of 36 ears was hand picked in order to secure uniformity at the milk stage, packed in ice, brought to Columbus and processed within 6 hours of harvest. Two pickings were made in 1949.

PROCESSING

All lots were processed in the pilot plant at Columbus, Ohio.

Tomatoes.—The tomatoes were blanched in steam for 30 seconds, immersed in cold water to cool, removed and peeled by hand. Representative wedge shaped samples from randomly selected tomatoes were taken for ascorbic acid, color and other analyses. In taking these samples equal portions of carpellary walls and gelatinous material surrounding the seeds were included.

The remainder of the tomatoes was ladled into No. 2 R-enamel tin cans and covered with expressed juice of tomatoes from the same lot. Entrapped air was worked out of the container with a stainless steel knife. The filled cans were immediately exhausted in steam until the contents had reached a temperature of 180° F. After sealing, the cans were processed at 212° F. for 35 minutes and cooled to about 105° F. in cold running water.

Sweet Corn.—Immediately after arrival at the laboratory, the sweet corn was hand-husked, silked and all defective areas removed. The ears were washed and the corn cut from the cob with a Food Machinery Corporation Universal #2 corn cutter equipped for cutting whole grain corn. The cut kernels were passed over an inspection belt where all defects were removed.

The cut kernels were washed, packed into previously sterilized #2 C-enamel cans, covered with salt brine (2 percent by weight in distilled water), exhausted until the contents had reached a temperature of 180° F., sealed and processed at 240° F. for 50 minutes and cooled to 105° F. in cold water.

Cabbage.—The heads were trimmed and then shredded in the laboratory model kraut cutter. Samples for fresh analyses were withdrawn. Thirty-five pounds of shredded cabbage, to which salt at the rate of 2.5 percent had been added, was packed into five-gallon earthenware jars and submerged beneath the level of extracted juice by means of inverted cake plates. The plates were weighted down with glass gallon jugs partly filled with water. A double layer of cheese cloth was placed over the jars to prevent the entrance of extraneous material. The cabbage was placed in a room (courtesy of Bacteriology Dept.) at 71.6° F. for approximately one month. Samples were removed as needed to determine when the fermentation had been completed. The No. 2 R-enamel tin cans were filled with fermented kraut exhausted to 180° F., sealed and cooled to 105° F. The use of R-enamel eliminated the customary bleaching which takes place when kraut is canned in plain tin cans.

QUALITY EVALUATIONS

Ascorbic Acid.—Ascorbic acid was determined by the modified method of Loeffler and Ponting (11).

Refractive Indices.—An Abbe Refractometer was used in determining refractive indices.

Alcohol Insoluble Solids.—Alcohol insoluble solids of the corn and cabbage were determined by the AOAC method for canned peas using 10 gram samples.

Alcohol Soluble Solids.—Fifty milliliter aliquotes of alcoholic extracts from the sugar extractions were evaporated to dryness in an oven at 100° C. to determine the alcohol soluble solids.

Sugar Analyses.—Reducing and total sugars were determined by the Shaeffer-Hartman copper reduction iodometric method (13).

Total Acidity.—Total acidity of sauerkraut expressed as lactic acid, was determined by titrating 10 ml. samples with N/9 sodium hydroxide, using phenolphthalein as an indicator.

Succulometer.—The succulometer values were used as measures of maturity in the sweet corn. The procedure consisted of soaking 100 gram samples in 200 ml. of water for 5 minutes, draining (2 minutes on an 8 mesh screen), and then expressing the juice at 500 pounds of pressure for 3 minutes. In obtaining the values for canned corn the soaking period was omitted. However, the corn was washed with 200 ml. of water before placing it on the screen to drain.

Color.—Color was determined by visual comparison with Maerz and Paul's Dictionary of Color (12).

The colors of tomatoes canned November 25, 1949, May 16, 1950 and October 27, 1951 were evaluated objectively by means of a Hunter Color and Color-Difference Meter. To make sure that the tomatoes canned on October 27, 1951 had attained the highest possible color, they were allowed to stand at room temperature at about 75° F., for 10 days after picking. This was done because of the low Hunter values obtained from the tomatoes picked on May 16, 1950 and October 27, 1951. These low values were secured in spite of the fact that the tomatoes were allowed to ripen on the vines prior to picking in order to approximate field conditions where tomatoes are desired for canning rather than for the greenhouse crop.

The Hunter Color and Color-Difference Meter has been used to evaluate the color of various food products objectively (8), (10), (14), (15). It is a photoelectric tristimulus colorimeter, measuring color on three scales which give uniform measures of the visual perceptibility of differences between colors (8). When measuring color of tomatoes three values for each color are obtained (1) "L" (visual lightness) which depends on the type of measuring circuit employed; (2) "a" which is redness when plus; and (3) "b" which is yellowness when plus.

In preparing the 1949 and 1950 samples for analyses the entire contents of the can were blended for 5 minutes in a Waring Blendor and strained through a cheesecloth. The tomatoes canned in 1951 were first emptied onto a 2-mesh grading screen (2 openings per inch) and drained 2 minutes. The juice and tomatoes were then extracted separately in a Cefaly laboratory pulper (.023 inch screen) to remove seeds. The colors of the juice and pureed whole tomatoes were then read on the Hunter Meter.

Organoleptic Evaluations.—Trained taste panels (9 to 10 members) were used to evaluate some of the samples of sweet corn and sauerkraut. Randomized samples from various fertility plots were graded on a preference basis.

RESULTS—TOMATO DATA—GREENHOUSE GROWN

Ascorbic Acid.—The ascorbic acid values expressed as mg/100 gm. fresh weight for the tomatoes grown in the greenhouses in 1948 and 1949 are presented in Tables 3 and 4. An examination of the data shows a higher mean value for ascorbic acid in the spring grown as compared to the fall grown tomatoes. These differences were significant at the one percent level in 1948.

There were definite decreases in ascorbic acid values for tomatoes grown in soil containing increasing amounts of nitrogen and phosphorus during both years. On the other hand tomatoes grown in soil containing increasing amounts of potassium contained increasing amounts of ascorbic acid for both years with the exception of the crop picked June 21, 1949. The decreased ascorbic acid values due to increasing increments of nitrogen are significant at the one percent level for all spring harvests including the means for 1948 and 1949. The decreases of

TABLE 3.—Ascorbic Acid Content of Scalded and Peeled Tomatoes as Affected by Varying Fertility Levels. (Expressed as mg/100 gms. of fresh tissue) 1948

Treatments	Date of Harvest												
	6/6	6/14	6/22	Mean spring crop	10/28	11/1	11/8	11/16	11/23	12/1	12/7	Fall crop	Mean all harvests
Minus NPK	——	14.3	12.4	13.4	22.1	13.0	13.9	11.0	17.8	15.3	15.2	15.5	15.00
Minus N	22.1	23.8	20.6	22.2	19.4	12.7	16.4	16.8	20.9	19.8	16.4	17.5	18.89
Low N	20.8	18.2	16.9	18.6	18.4	15.2	15.4	15.4	19.4	19.3	15.2	16.9	17.42
Med. N	18.2	17.0	14.8	16.7	17.6	9.8	13.4	12.5	17.8	16.1	14.1	14.5	15.13
High N	17.1	18.4	14.1	16.5	15.2	8 9	13.9	10.2	15.6	16.0	14.6	13.5	14.45
Very high N	16.7	16.8	13.1	15.6	14.8	15.5	10.6	12.1	13.6	14.5	12.2	13.3	13.99
Minus P	18.5	17.0	16.5	17.3	21.0	11.1	17.4	14.6	17.4	20.5	18.5	17.2	17.25
Low P	17.5	17.8	15.1	16.8	16.6	8.9	16.2	12.7	17.7	16.1	16.4	14.9	15.50
Med. P	18.3	16.6	15.5	16.8	16.2	9.9	15.5	11.7	16.2	17.2	13.9	14.4	15.10
High P	18.0	15.7	11.4	15.0	15.5	10.1	13.9	11.5	13.3	15.2	13.8	13.3	13.84
Very high P	16.9	14.3	11.2	14.1	14.2	9.5	11.9	10.0	14.8	16.8	12.9	12.9	13.25
Minus K	19.4	13.5	14.9	15.9	18.5	9.0	9.4	10.1	13.9	16.4	16.0	13.3	14.11
Low K	19.1	15.6	12.7	15.8	17.4	9.4	10.3	12.9	14.8	16.0	17.1	14.0	14.53
Med. K	19.3	17.4	16.6	17.8	18.0	10.8	10.9	10.3	16.8	19.7	19.2	15.1	15.90
High K	19.5	17.4	20.5	19.1	18.8	10.3	10.2	10.4	18.4	21.0	22.9	16.0	16.94
Very high K	22.0	17.6	24.7	21.4	19.4	9.9	13.0	14.4	21.4	23.9	22.8	17.8	18.91
Mean	18.89	17.17	15.91	17.1	17.40	10.73	13.23	12.37	16.80	17.90	16.40	15.0	15.68

L.S.D. at 1% level for fertilizer differences. Spring crops 4.04, Fall crops 2.65.
L.S.D. at 1% level for dates of harvest Spring and Fall crops 3.13.

TABLE 4.—The Ascorbic Acid Content of Scalded and Peeled Tomatoes as Affected by Varying Fertility Levels. (Expressed as mg/100 gms. of Fresh Tissue) 1949

Treatment	Date of Canning											
	5/10 1949	5/18 1949	6/4 1949	6/21 1949	Mean spring	10/17 1949	10/31 1949	11/7 1949	11/21 1949	12/5 1949	Fall crops	All crops
Minus NPK	24.1	19,3	18.1	14.3	19.0	14.0	14.1	14.0	14.3	14.5	14.2	16.3
Minus N	22.2	18.0	19.2	25.3	21.2	16.3	16.3	15.1	16.2	15.2	15.8	18.2
Low N	18.4	17.9	18.6	22.4	19.3	16.4	15.8	16.3	16.2	16.4	16.2	17.6
Med. N	16.3	16.4	16.5	20.2	17.4	15.8	15.2	16.1	16.3	16.6	16.0	16.6
High N	14.9	14.1	15.0	17.4	15.4	15.0	12.6	14.3	13.2	14.0	13.8	14.5
Very high N	16.2	14.5	15.5	12.9	14.8	14.5	14.3	12.3	11.2	12.8	13.0	13.8
Minus P	18.3	17.0	17.1	16.3	17.2	15.0	15.0	15.8	15.1	15.3	15.2	16.9
Low P	13.9	14.0	14.3	16.3	14.6	17.0	13.6	13.8	13.6	15.2	14.6	14.7
Med. P	10.3	17.8	15.3	15.8	14.8	16.9	14.2	14.3	12.6	15.1	14.6	14.7
High P	13.8	14.6	13.9	12.8	13.8	15.0	15.0	15.1	14.6	13.8	14.7	14.2
Very high P	13.6	13.7	13.6	11.2	13.0	13.3	13.6	13.0	14.7	13.0	13.5	13.3
Minus K	16.3	8.6	15.3	17.8	14.5	13.6	12.6	12.1	13.6	13.4	15.1	13.7
Low K	16.8	12.5	16.8	15.1	15.3	15.0	15.1	14.3	15.1	14.8	14.9	15.1
Med. K	21.2	16.4	19.3	14.9	18.0	14.9	14.7	12.1	15.1	14.5	14.3	15.9
High K	21.3	17.3	20.1	15.1	18.5	15.5	16.5	13.3	16.3	15.8	15.5	16.8
Very high K	22.3	20.5	19.8	15.4	19.5	15.8	16.8	15.6	16.5	16.6	16.3	17.7
Mean	17.5	15.8	16.8	16.5	16.7	15.3	14.7	14.2	14.7	14.2	14.8	15.65

Least significant difference for components (NP & K) at one percent level. Spring crop 3.34, Fall crop, 2.98.
Least significant difference for the date of harvest at one percent level. Spring and Fall crops 2.98.

ascorbic acid due to increased increments of nitrogen are also significant at the one percent level for 8 out of 12 fall crop harvests. In only one instance, i. e., November 1, 1948 was the trend reversed and in this instance three of the five determinations follow the general trend.

On the other hand only 5 of the 10 spring crops and 5 of the 12 fall crops show a decrease in ascorbic acid, significant at the one percent level for increasing levels of phosphorus. However, there is an actual decrease in the ascorbic acid content for everyone of the 19 harvests made in 1948 and 1949 as the level of phosphorus increased.

The increases in ascorbic acid due to increasing increments of potassium are significant at the one percent level for 5 out of 7 spring and 4 out of 12 fall harvests. However, the ascorbic acid content of the tomatoes at each harvest, with the exception of the harvest of June 21, 1949, increased as the potassium level of the soil increased.

The effects of approximately 6 months storage, after canning, on the ascorbic acid contents of tomatoes grown in the greenhouse are shown in Tables 5, 6 and 7 and Charts 1 and 2.

The losses of ascorbic acid for the six month periods vary from 5.91 percent to 36.2 percent for individual lots for the two years. The greatest loss was from the tomatoes grown in soil in the plot supplying inadequate amounts of all three major fertility elements N, P and K. No other effect attributable to fertilizer levels could be detected.

The data for both years by seasons are summarized in Table 8. These data indicate an average ascorbic acid value of 17 mg/100 gm. for the spring crops of tomatoes and 14.8 mg/100 gm. for the fall crops. After a storage period of 6 months in cans at room temperatures the spring crops averaged 12.5 mg/100 gm. (a loss of 4.5 mg/100 gm.) and the fall crops 12.8 mg/100 gm. (a loss of 2 mg/100 gm.). The data are available for a few canned lots (average of 8 to 16 lots) after 11 to 12 and after 17 months storage. The loss after 11 and 12 months storage is not significantly greater than after 6 months storage. After 17 months storage an additional loss of ascorbic acid is clearly indicated.

Data for the ascorbic acid contents of four lots of fall canned tomatoes after 6 and 12 month storage are given in Table 9. No consistent effect of fertility levels on the loss of ascorbic acid in canned tomatoes can be detected.

No attempt was made to secure evaluations of quality from field grown tomatoes as the fertility levels of the field plots were not adequately controlled, although those in the greenhouse were checked by visual symptoms and by fertilizer treatments as previously described.

Refractive Indices.—Typical refractive indices for fresh tomatoes for 1948 and 1949 are given in Table 10. No differences due to fertility

TABLE 5.—The Ascorbic Acid Content of Canned Tomatoes as Affected by Varying Fertility Levels. (Expressed as mg/100 gms. Fresh Tissue). 1948

Treatment	Date of Canning 6-7-48 / Date Analyzed 12-8-48	6-15-48 / 1-10-49	6-23-48 / 1-12-49	10-29-48 / 1-11-49	11-2-48 / 1-17-49	11-9-48 / 1-18-49	11-17-48 / 1-20-49	11-24-48 / 1-20-49	12-1-48 / 1-25-49	12-7-48 / 1-26-49	Mean canned	Fresh	Percent loss
Minus NPK	——	12.0	10.2	19 6	11.0	11.0	6 9	14.7	13.0	13.8	11.2	15.0	25.3
Very low N	20.5	21.2	19.1	18.2	10.9	15.1	13.8	18 8	17.6	14.2	16 9	18.9	10.6
Low N	19.7	17.2	15.4	16.0	12.9	13.9	12.9	16.9	16.2	12.9	15.4	17.4	11.5
Med. N	17.6	16.1	12.5	15.0	7.7	11.8	10.6	15.6	14.1	11.9	13 3	15.1	11.9
High N	15.9	16.2	11.3	12.1	6.4	11.9	9.3	12.6	17.4	12.0	12.5	14.5	13.8
Very high N	14.0	14.4	10.3	12.5	12.9	7.8	9.3	11.3	11.2	12.2	11.6	14.0	17.1
Very low P	17.4	16.4	14.6	19.6	10.1	15.4	12.9	15.7	18.3	9.0	14.9	17.3	13 9
Low P	14.6	16.7	12.7	15.7	6.9	14.3	10.6	16.0	15.0	15.9	13.9	15.5	10.3
Med. P	17.8	14.9	11.7	14.4	7.9	12.9	9.4	13.1	15.1	14.2	13.1	15.1	13.2
High P	15.5	13.6	10.1	12.9	7.8	11.0	9.9	10.8	13.2	11.8	11.7	13.8	15.2
Very high P	13.7	9.3	8.1	10.4	6.1	9.7	7.4	11.7	13.4	10.7	10.0	13.3	24.8
Very low K	18.2	12.6	12.3	16.9	6.2	6.8	8.2	11.3	14.0	13 9	12.0	14 1	14.9
Low K	17.1	13.0	10.4	15.6	8.3	8.1	9.6	12.6	13.1	14.9	12.3	14.5	15.2
Med. K	18.7	15.9	15.4	17.3	8.2	8.4	8.5	13.9	17.3	17.0	14.1	15.9	11.3
High K	17.6	16.0	19.7	18.5	9.2	8.9	8.5	16.4	19.0	20.3	15.4	16.9	8.9
Very high K	21.1	16.1	21.4	17.9	7.9	11.2	12.4	19.3	21.8	20.3	16.9	18.9	10.6
Mean	17.3	15.1	13.4	15.8	8.8	11.1	10.0	14.4	15.6	14.1	13.5	15.6	——

L.S.D. at 1% level dates of harvest 3.13.
L.S.D. at 1% level treatments 2.65.

TABLE 6.—The Ascorbic Acid Content of Canned Tomatoes as Affected by Varying Fertility Levels. (Expressed as mg/100 gms. of Fresh Tissue). 1949

Treatment	Date of Canning									Fresh	Mean canned	Percent loss
	5/13/49	5/18/49	6/4/49	6/21/49	10/19/49	11/4/49	11/11/49	11/25/49	12/9/49			
	Date Analyzed											
	1/5/50	1/9/50	1/7/50	1/4/50	1/16/50	1/12/50	1/18/50	1/17/50	1/19/50			
Minus NPK	9.0	6.9	7.0	11.5	8.5	11.2	13.2	14.3	12.0	16.3	10.4	36.2
Minus N	13.8	12.4	18.1	12.1	16.2	12.5	14.3	12.6	13.6	18.2	14.0	23.1
Low N	12.4	13.5	12.7	15.8	15.9	13.5	15.1	13.8	14.3	17.6	14.1	20.0
Med. N	9.8	10.3	12.2	14.0	12.4	13.4	14.4	15.0	12.8	16.6	12.7	23.5
High N	12.1	10.5	11.9	10.8	10.1	12.2	11.2	11.9	12.7	14.5	11.5	20.6
Very high N	10.0	10.3	9.5	10.2	15.4	14.0	10.5	10.6	11.2	13.8	11.3	18.2
Minus P	10.5	7.1	10.5	14.0	13.8	14.1	14.6	13.7	13.3	16.9	12.4	26.6
Low P	11.9	6.7	7.4	9.4	16.2	13.0	12.9	13.0	13.0	14.7	11.5	21.8
Med. P	9.2	9.8	7.0	11.1	12.8	12.5	13.6	11.8	13.0	14.7	11.2	23.8
High P	10.9	8.8	8.2	12.4	9.2	12.5	12.2	14.3	12.3	14.2	11.2	20.4
Very high P	9.8	7.6	8.0	10.2	8.8	12.8	13.8	14.2	11.1	13.3	10.7	19.6
Minus K	11.9	6.2	5.1	11.7	11.2	12.0	12.0	11.9	11.3	13.7	10.5	23.4
Low K	12.9	8.8	9.2	9.2	12.2	12.5	12.2	13.0	12.6	15.1	11.4	24.5
Med. K	12.7	9.8	8.4	10.1	12.6	12.5	9.4	11.6	12.8	15.9	11.1	30.3
High K	12.0	10.3	10.2	13.6	13.4	12.6	12.6	12.4	13.6	16.8	12.3	26.8
Very high K	14.2	7.7	13.0	12.3	12.8	10.7	12.7	11.6	13.9	17.7	12.1	31.7
Mean	11.4	9.2	9.9	11.2	12.6	12.6	12.8	12.9	12.7	15.6	11.8	24.4

L.S.D. at 1% level dates of harvest 3.13.
L.S.D. at 1% level treatments 2.65.

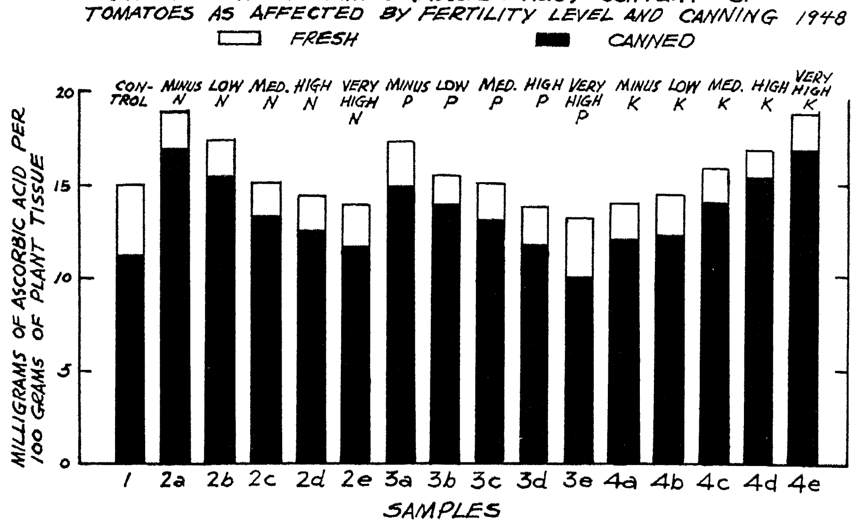
TABLE 7.—Ascorbic Acid Content of Fresh and Canned Tomatoes as Affected by Fertility Levels and Canning. (Expressed as mg/100 gms. Fresh Tissue). Figures in Parentheses Indicate Number of Duplicate Determinations Included in Means

Treatment	Mean Values Fresh Tomatoes				
	Date of Canning				
	6/ 6/48 6/22/48 (3)	10/28/48 12/ 7/48 (7)	5/10/49 6/21/49 (4)	10/17/49 12/ 5/49 (5)	5/16/50 6/ 6/50 (2)
Minus NPK	13.4(2)	15.5	19.0	14.2	16.4
V. Low N	22.2	17.5	21.2	15.8	24.0
Low N	18.6	16.9	19.3	16.2	21.8
Med. N	16.7	14.5	17.4	16.0	19.5
High N	16.5	13.5	15.4	13.8	15.9
V. high N	15.6	13.8	14.8	13.0	15.8
V. low P	17.3	17.2	17.2	15.2	19.3
Low P	16.8	14.9	14.6	14.6	17.3
Med. P	16.8	14.4	14.8	14.6	14.1
High P	15.0	13.3	13.8	14.7	13.9
V. high P	14.1	12.9	13.0	13.5	12.6
V. low K	15.9	13.5	14.5	15.1	8.4
Low K	15.8	14.0	15.3	14.9	15.1
Med. K	17.8	15.1	18.0	14.3	16.9
High K	19.1	16.0	18.5	15.5	21.6
V. high K	21.4	17.8	19.5	16.3	22.0
Mean	17.1	15.0	16.7	14.8	17.2

	Mean Values Canned Tomatoes					
	Date Canned					
	June 48	Oct.-Dec. 48	May-June 49	Oct.-Dec. 49	May-June 50	Nov. 49
	Date Analyzed					
	Jan. 49(3)	Jan. 49(7)	Jan. 50(4)	Jan. 50(5)	Apr. 51(2)	Apr. 51(2)
Minus NPK	11.1(2)	12.8	8.6	11.8	15.0	10.8(1)
V. Low N	20.4	15.5	14.1	13.8	16.5	12.7(1)
Low N	17.4	14.5	13.6	14.5	15.8	10.6
Med. N	15.4	12.4	11.6	13.6	17.6	10.6
High N	14.5	11.7	11.3	11.6	14.1	10.7
V. high N	12.9	11.0	10.0	12.3	14.0	10.1
V. low P	16.1	14.4	10.5	13.9	16.2	11.6
Low P	14.7	14.5	8.9	13.6	13.7	11.9
Med. P	14.8	12.4	9.3	12.7	13.2	12.8
High P	13.0	11.1	10.1	12.1	13.1	10.6
V. high P	10.4	9.7	8.9	12.1	13.4	9.3
V. low K	14.4	11.0	8.7	11.7	9.4	11.1(1)
Low K	13.5	11.7	10.0	12.5	12.9	8.5(1)
Med. K	16.7	12.9	10.2	11.8	15.0	11.1(1)
High K	17.8	14.4	11.5	12.9	15.5(1)	11.1(1)
V. high K	19.5	15.8	11.8	12.3	16.1	12.6(1)
Mean	15.2	12.8	10.5	12.7	14.5	11.0

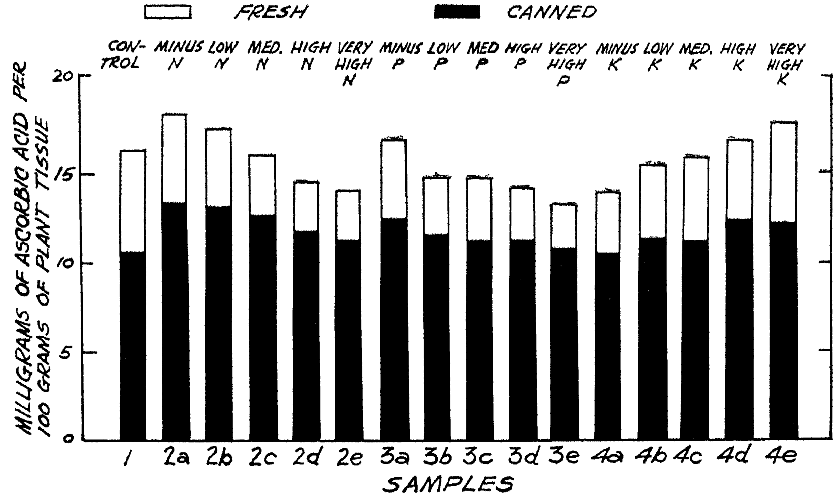
L.S.D. at 1% level dates of harvest 3.13
L.S.D. at 1% level treatments 2.65

CHART 1 THE VITAMIN C (ASCORBIC ACID) CONTENT OF TOMATOES AS AFFECTED BY FERTILITY LEVEL AND CANNING 1948



levels can be detected. Refractive indices of fall (1949) and spring (1950) canned tomatoes are given in Table 11. It is obvious that the indices of the spring grown tomatoes are higher than the fall grown tomatoes. Thus the ascorbic acid content as well as soluble solids (as measured by the refractometer) are both higher in the spring grown fruits.

CHART 2 THE VITAMIN C (ASCORBIC ACID) CONTENT OF TOMATOES AS AFFECTED BY FERTILITY LEVEL AND CANNING 1949



However, in only one instance, i. e., the potassium series in the 1950 spring crop, did the increasing refractive indices of tomatoes grown on different fertility levels parallel the increasing vitamin C contents. In this instance there seems to be a definite increase in refractive indices as well as ascorbic acid with increased levels of potassium in the soil. It is interesting to note that the refractive indices of the tomatoes grown in the soil in the unfertilized plots, i. e., minus N, P, K, are always relatively low.

Color.—The color of the processed tomatoes was visually compared with plates in Maerz and Paul's Dictionary of Color (12). Some of the data are presented in Table 12.

In interpreting the values in any entry (Table 12), the K values are of better color than the J values and the J values are in turn better than the I values. In a like manner the larger numbered values (last figure) usually indicate better color than the smaller values in this table. The first number in every instance designates the plate number. These data are limited in value because they are subject to individual

TABLE 8. The Ascorbic Acid Content of Fresh and Canned Tomatoes as Affected by Dates of Harvest. mg/100 gms. Greenhouse Grown

Date canned	Mean value 16 treatments fresh tomatoes	6 month storage	Mean values 16 treatments* 11-12 month storage	17 month storage
5/10/49	17.5	11.4		
5/16/50	17.5	——	16.35	
5/18/49	15.8	9.2		
6/ 4/49	16.8	9.9		
6/ 6/48	18.9	17.3		
6/ 6/50	16.8	——	12 38(15)	
6/14/48	17.7	15.1		
6/21/49	16.5	11.2		
6/22/48	15.9	13.4		
Weighted mean	17.0	12.5	14 4	
10/17/49	15.3	12.6		
10/28/48	17.4	15.8		
10/31/49	14.7	12.6		11.70(8)
11/ 1/48	10.7	8.8		
11/ 7/49	14.2	12.8		
11/ 8/48	13.2	11.1		
11/16/48	12.4	10.0		
11/21/49	14.7	12.9		10.57
11/23/48	16.8	14.4		
12/ 1/48	17.9	15.6		
12/ 5/49	14.2	12.7		
12/ 7/48	16.4	14.1		
Weighted mean	14 8	12 8		10.9

*Values in parentheses indicate number of treatments included if the number is less than 16.

TABLE 9.—The Ascorbic Acid Content of Canned and Peeled Tomatoes as Affected by Varying Fertility Levels. (Expressed as mg/100 gms. of Tissue). 1948

Treatment	Date of Canning and Analysis					
	Nov. 8, 1948			Nov. 16, 1948		
	F	S	Y	F	S	Y
Minus NPK	13.9	10.9	12.6	11.0	6.9	15.3
Minus N	16.4	15.1	13.6	16.8	13.8	16.2
Low N	15.4	13.9	15.3	15.4	12.9	14.9
Med. N	13.4	11.7	9.1	12 5	10.6	12.4
High N	13.9	11.9	11.0	10.2	9.3	9.6
V. high N	10.6	7 7	10.5	12.1	9.3	10.5
Minus P	17.4	15.4	15.8	14.6	12.9	14.7
Low P	16.2	14.3	9.9	12.7	10.6	12.3
Med. P	15.5	12.9	8.2	11.7	9.4	10.6
High P	13.9	11.0	8.1	11.5	9.9	10.6
V. high P	11.9	9.7	10.6	10.0	7.4	10.4
Minus K	9.4	6.8	8.6	10.1	8.2	10.4
Low K	10.3	8.0	10.1	12.9	9.6	10.6
Medium K	10.9	8.4	9.6	10.3	8.5	9.6
High K	10.2	8.9	9.7	10.4	8.5	9.6
V high K	13.0	11.2	12.1	14.4	12.4	12.2
	Dec. 1, 1948			Dec. 7, 1948		
	F	S	Y	F	S	Y
Minus NPK	15.3	13.0	11.7	15.2	13.8	11.1
Minus N	19.8	17.6	9.7	16.4	14.2	11.7
Low N	19.3	16.2	8.5	15.2	12.9	12.0
Mod. N	16.1	14.1	11.1	14.1	11.9	11.7
High N	16.0	17.4	8 5	14.6	12.0	12.0
V. high N	14.5	11.2	12.0	12.2	12.2	13.8
Minus P	20.5	18.3	9.3	18.5	9.0	11.7
Low P	16.1	15.0	10.3	16.4	15.9	13.8
Med. P	17.2	15.1	12.0	13.9	14.2	9.3
High P	15.2	13.2	9.3	13.8	11.8	13.2
V. high P	16.8	13.4	12.0	12.9	10.7	11.9
Minus K	16.4	14.0	9.3	16.0	13.9	10.5
Low K	16.0	13.1	13.8	17.1	14.9	9.3
Medium K	19.7	17.3	9.7	19.2	17.0	13.2
High K	21.0	19.0	9.3	22.9	20.3	14.0
V. high K	23.9	21.8	6.5	22.8	20.3	14.6

F—Fresh tomatoes.
S—Canned tomatoes after six month storage.
Y—Canned tomatoes after twelve month storage.

abilities to distinguish color differences. Most of the lots canned November 25, 1949 and May 16, 1950 were later evaluated by the Hunter Meter.

An inspection of Table 12 does not reveal any consistent effects of treatment on the color of tomatoes. The table does show that the tomatoes from the plots receiving heavy applications of phosphorus and potassium do have good colors. However, if the color evaluations for the two fall pickings October 19, 1949 and November 4, 1949 are compared to the two spring pickings May 16, 1950 and June 8, 1950, it is obvious that the spring grown tomatoes are more highly colored. In the fall pickings there are 10 lots that are evaluated with an F color or worse though only 1 lot from the spring crops was given such a low evaluation. Likewise only 12 fall grown lots were evaluated as having I colors or better. This compared with 27 lots from the spring grown crops that were evaluated I or above. Thus it is obvious that subjective color evaluations can be used as measures of color differences and that tomatoes grown in the greenhouse during the spring are more highly colored than those grown in the fall.

TABLE 10.—Refractive Indices and Total Solids of Fresh Tomatoes Grown in the Greenhouse. 1948 and 1949*

Treatment No.	1948 Crop Ref. index	1948 Crop % T.S.	1949 Crop Ref. index	1949 Crop % T.S.
	Fresh		Fresh	
Minus NPK	1.3404	5.87	1.3400	5.60
Minus N	1.3412	6.43	1.3405	5.95
Low N	1.3411	6.35	1.3409	6.23
Med. N	1.3415	6.65	1.3411	6.35
High N	1.3413	6.50	1.3408	6.15
V. high N	1.3416	6.73	1.3413	6.50
Minus P	1.3416	6.73	1.3412	6.43
Low P	1.3412	6.43	1.3412	6.43
Med. P	1.3412	6.43	1.3412	6.43
High P	1.3410	6.30	1.3413	6.50
V. high P	1.3410	6.30	1.3408	6.15
Minus K	1.3420	7.00	1.3401	5.67
Low K	1.3405	5.95	1.3405	5.95
Med. K	1.3403	5.80	1.3405	5.95
High K	1.3410	6.30	1.3405	5.95
V. high K	1 3413	6.50	1.3411	6.35
Ave.	1.3411	6.35	1.3408	6.15

*Conversions by Chart revised 1935 from Bulletin 27-L National Canners Association. Corrected for 25° C.

TABLE 11.—The Refractive Index of Canned Tomatoes as Affected by Fertility Levels. 1949 and 1950

Treatment	Dates Canned						Average 1949 (Four pickings)	Average 1950 (Two pickings)
	10-19-49	11-4-49	11-10-49	11-25-49	5-16-50	6-8-50		
Minus NPK	———	1.3405	1.3390	1.3400	1.3409	1.3410	1.3398*	1.3410
Minus N	1.3400	1.3410	1.3403	1.3404	1.3421	1.3420	1.3404	1.3421
Low N	1.3408	1.3400	1.3400	1.3410	1.3432	1.3428	1.3404	1.3430
Med. N	1.3405	1.3410	1.3405	1.3402	1.3430	1.3420	1.3405	1.3425
High N	1.3403	1.3420	1.3405	1.3419	1.3422	1.3423	1.3412	1.3423
Very high N	1.3419	1.3420	1.3415	1.3410	1.3430	1.3445	1.3416	1.3438
Minus P	1.3412	1.3412	1.3409	1.3406	1.3420	1.3420	1.3410	1.3420
Low P	1.3412	1.3416	1.3420	1.3412	1.3422	1.3429	1.3415	1.3425
Med. P	1.3403	1.3420	1.3418	1.3412	1.3415	1.3430	1.3413	1.3423
High P	1.3410	1.3418	1.3415	1.3410	1.3420	1.3422	1.3415	1.3421
Very high P	1 3410	1.3413	1.3408	1.3412	1.3415	1.3421	1.3411	1.3418
Minus K	1.3410	1.3412	1.3390	1.3404	1.3400	1.3412	1.3404	1.3406
Low K	1.3403	1.3400	1.3396	1.3416	1.3424	1.3422	1.3404	1.3423
Med. K	1.3400	1.3405	1.3409	1.3420	1.3430	1.3426	1.3409	1.3428
High K	1.3385	1.3405	1.3400	1.3405	1.3430	———	1.3397	1.3430†
Very high K	1.3409	1.3403	1.3399	1.3410	1.3430	1.3440	1.3405	1.3435
Ave.	1.3406	1.3411	1.3405	1.3409	1.3422	1.3425	1.3408	1.3424

*Average of three pickings. †One picking only.

The data from the Hunter readings are shown in Tables 13 and 14 and in Chart 3. From an examination of the aL/bL ratios in Table 13 it is apparent that the spring canned tomatoes have the higher ratios. Since high values for these ratios are associated with a greater intensity of the red color it may be assumed that the spring grown tomatoes are more highly colored. This agrees with the subjective evaluations shown in Table 12. This redder color found in the spring crops may possibly be due to more sunlight. Records show that there were 773 hours of sunlight during the months of September, October, November and December 1949 as compared to 968 hours of sunlight during the months of March, April, May and June of 1950. No effect of fertilizer treatment on the intensity of color as measured by the Hunter Meter can be detected. This also agrees with the subjective evaluations. The aL/bL values were, however, much lower than published values (14, 15). It is thought that the low values in Table 13 may be due to the effect of seed which may have become pulverized during the 5 minute treatment in the Waring Blendor.

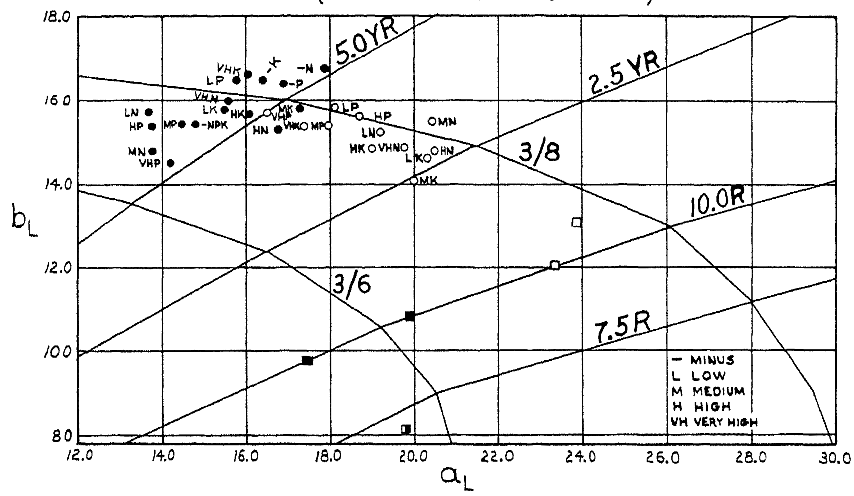
As indicated in the methods of procedure a separate lot of Globe A tomatoes (grown in the greenhouse) were thoroughly ripened in the laboratory and prepared so that the seed was removed without any chance of comminution. As shown in Table 14 the color of these lots

TABLE 12.—Color of Canned Tomatoes by Visual Comparison to Plates in Maerz and Paul's Dictionary of Color as Affected by Varying Fertility Levels and Canning

Treatment	Date Canned					
	10-19-49	11-4-49	11-10-49	11-25-49	5-16-50	6-8-50
Minus NPK	3-F-12	3-I -11	3-J -11	3-H-11	3-I -11	3-H-12
Minus N	3-F-10	3-I -11	3-E-11	3-H-11	3-I -11	3-K-11
Low N	3-I -11	3-I -11	3-G-12	4-I -11	3-I -10	3-I -12
Medium N	3-F-11	3-G-11	3-G-11	4-I -11	3-J -11	3-J -12
High N	3-C-11	3-H-11	3-D-12	4-J -11	3-J -11	3-J -12
V. high N	3-C-11	3-H-11	3-I -11	4-J -12	3-I -11	3-I -12
Minus P	3-D-11	3-E-11	3-F-12	3-I -11	3-K-11	3-K-12
Low P	3-D-11	3-I -11	3-H-11	4-J -10	3-I -11	3-J -11
Medium P	3-H-11	3-I -11	3-D-12	4-I -11	3-I -11	3-J -11
High P	3-H-11	3-I -12	3-I -11	4-J -10	3-I -11	3-H-11
V. high P	3-H-12	3-H-12	3-I -11	4-K-11	3-I -11	3-I -11
Minus K	3-I -11	3-J -11	3-H-11	3-H-11	3-I -11	3-I -12
Low K	3-F-11	3-H-11	3-I -11	3-K-11	3-F-12	3-K-11
Medium K	3-I -11	3-J -11	3-H-11	4-K-11	3-K-12	3-K-11
High K	3-H-11	3-C-11	3-H-11	4-L -11	3-J -11	———
V. high K	3-G-11	3-I -11	3-G-11	4-J -11	3-H-11	3-J -12

as measured by the Hunter Meter is much superior to any of the lots included in Table 13. These colors compare favorably with that of Grade A tomatoes as described in the literature (10), (14), (15). From this it is obvious that excellent color can be developed in tomatoes grown under glass. It is also evident that considerable color was lost by processing, as the raw product had an aL/bL ratio of 2.44 though the processed juice and canned tomatoes from these fresh tomatoes had ratios which ranged from 1.79 to 1.93. These differences are presented graphically in Chart 3.

CHART NO 3. CHROMATICITY DIAGRAM SHOWING HUNTER COLOR DIFFERENCE METER VALUES OF GREENHOUSE GROWN TOMATOES CANNED IN FALL 1949, SPRING 1950, FALL 1951.
HUNTER a_L/b_L VALUES OF:
● TOMATOES CANNED 11-25-49. (ENTIRE CAN CONTENTS, INCLUDING JUICE.)
○ TOMATOES CANNED 5-16-50. (ENTIRE CAN CONTENTS, INCLUDING JUICE.)
□ TOMATOES CANNED 10-27-51. (DRAINED AND PUREED WHOLE TOMATOES.)
■ TOMATOES CANNED 10-27-51. (DRAINED JUICE.)
◧ RAW TOMATOES. (PUREED SAMPLE EVALUATED 10-27-51.)



SWEET CORN DATA—FIELD GROWN

The alcohol insoluble solids content and succulometer readings for the fresh and canned sweet corn grown in 1948 and for two harvests in 1949 are shown in Table 15. No differences attributable to fertilizer treatments are evident in the 1948 data, although there is a slight decrease in AIS values as the nitrogen level of the soil increases.

Alcohol insoluble solids are much higher for the second than for the first harvests in 1949. Since high alcohol insoluble solids are associated with advanced maturity it is obvious that the second harvest in 1949 was a little more mature than the harvest made in 1948. Obviously the first harvest in 1949 was very immature because it had an average alcohol insoluble solids content of 10.6 and an average succulometer reading of 27.9 ml. per 100 gms. However, both the 1948 and the 2nd harvest for 1949 are well under the 27 percent AIS maximum value established by the Food and Drug Administration as the minimum standard of quality for sweet corn.

The succulometer values on the other hand indicated that the second harvest for 1949 was less mature than the 1948 harvest as greater succulence is usually associated with the less mature corn. However, as stressed in Research Circular 19, succulence as measured by the Succulometer is not a reliable measure of maturity. For further information on AIS and the Succulometer as measures of quality, see Ohio Agricultural Experiment Station Research Circular 19 (6).

Refractive indices were secured in 1949. No consistent effects of fertility levels can be identified. The lowered values of the indices after canning is attributed to the leaching action of the brine. (See Table 16).

The ascorbic acid values decrease upon canning and storage. No trends due to fertility levels could be detected. Likewise no effects due to fertility levels on the total sugar contents could be identified. The loss of total sugars upon canning is attributed to the leaching action of the brine.

TABLE 13.—Color of Canned Tomatoes (Globe Strain A) as Affected by Varying Fertility Levels and Canning, as Measured by the Hunter Color and Color-Difference Meter. (Analyzed April 24, 1951)

Treatment	Designation	Canned November 25, 1949				Canned May 16, 1950			
		L	aL	bL	aL bL	L	aL	bL	aL bL
Minus NPK	—NPK	31.5	14.8	15.4	.96	—	—	—	—
Minus N	—N	34.0	17.9	16.8	1.07	—	—	—	—
Low N	+N	33.3	13.7	15.7	.97	32.3	19.2	15.1	1.27
Medium N	++N	31.0	13.8	14.8	.93	32.1	20.4	15.5	1.32
High N	+++N	31.7	16.8	15.3	1.10	32.0	20.5	14.8	1.39
V. high N	++++N	33.3	15.6	16.0	.98	31.7	19.8	14.9	1.33
Minus P	—P	33.5	16.9	16.4	1.03	—	—	—	—
Low P	+P	33.5	15.8	16.5	.96	34.1	18.1	15.8	1.15
Medium P	++P	32.0	14.5	15.4	.94	32.7	18.0	15.4	1.17
High P	+++P	31.8	13.8	15.4	.90	32.9	18.7	15.6	1.20
V. high P	++++P	30.7	14.2	14.5	.98	33.2	16.5	15.7	1.05
Minus K	—K	33.9	16.4	16.5	.99	—	—	—	—
Low K	+K	32.6	15.5	15.8	.98	29.5	20.3	14.6	1.39
Medium K	++K	31.6	17.3	15.8	1.09	21.4	20.0	14.1	1.42
High K	+++K	32.3	16.1	15.7	1.03	30.9	19.0	14.8	1.28
V. high K	++++K	33.4	16.1	16.6	.97	32.3	17.4	15.4	1.13

Thus though the yield of sweet corn was increased in 1949 from 12,496 to 14,120 pounds per acre by increased levels of nitrogen and from 11,952 to 13,240 pounds per acre by increased levels of phosphorus and from 11,020 to 13,600 by increased levels of potassium (See Table 2), there does not seem to be any detectable effects on the alcohol insoluble solids, succulometer readings, refractive indices, ascorbic acid content or total sugars.

CABBAGE DATA—FIELD GROWN

The average weight of cabbage heads, and total and reducing and non-reducing sugars, and ascorbic acid contents of the fresh cabbage and sauerkraut after six months storage for the 1948 and 1949 crops are shown in Table 17.

The ascorbic acid content as well as the total sugar content of the cabbage grown in 1949 decreased as the nitrogen level of the soil in which the cabbage grew was increased. Likewise the ascorbic acid content of the cabbage grown the same year tended to increase as the potassium level in the soil increased. This corresponds to similar trends with the tomatoes grown under controlled conditions in the greenhouse. The data secured in 1948 do not indicate any definite trends. No differences in reducing and non-reducing sugars attributable to fertility levels can be dètected.

TABLE 14.—Color of Greenhouse Tomatoes (Globe Strain A) as Measured by the Hunter Color and Color-Difference Meter. Canned October 27, 1951 and Analyzed March 14, 1952*

Sample	L	aL	bL	aL bL Ratio
Raw product	21.1	19.8	8.1	2.44
Canned product (Drained tomatoes) (No defects)	26.1	23.9	13.1	1.82
Drained juice	23.2	19.9	10.8	1.84
Canned product (Drained tomatoes) (Defective)	24.8	23.4	12.1	1.93
Drained juice	22.0	17.5	9.8	1.79

*Tomatoes picked October 15th and 19th, 1951. Lot picked on 15th put in 32° F. storage on 19th, from 21st to 27th stored at room temperature. Lot picked on 19th held at room temperature until canned on October 27th.

The losses of ascorbic acid after 6 months are large.

Table 18 shows the losses of ascorbic acid after 6 and 12 months storage at room temperatures. Obviously the kraut lost little additional ascorbic acid during the last 6 months storage. Apparent increases can be attributed to variations within samples.

Thus cabbage yielding as little as 16,220 pounds per acre (see Lot 6, Table 2) had an average ascorbic acid content of 28.8 mg/100 gm. while that yielding 38,520 pounds per acre (see Lot 2, Table 2) had

TABLE 15.—Alcohol Insoluble Solids and Succulometer Data—Sweet Corn Grown at Marietta, Ohio. 1949 and 1950

Treatment	Alcohol Insoluble Solids						
	1948		1949				
			1st harvest		2nd harvest		
	Raw	Canned 6 mo.	Raw	Canned 6 mo.	Raw	Canned 6 mo.	Canned 21 mo.
—N	15 6	17.3	10.0	9 3	19.1	18.2	19.6
+N	17.4	19 0	10.1	9.4	19.0	17.9	18.4
++N	14.2	17.7	10 1	9 3	18.6	17 5	19.8
—P	14.6	16.5	12.6	11 5	17.0	15.7	20.5
+P	16.9	18.4	10.8	9 8	18.2	16.7	19.2
—K	16.4	19.4	10.4	9 3	17.0	15.2	20.4
+K	15.5	16.7	10.9	9.7	18.9	17.6	19.7
++K	15 2	17.3	10.0	8 9	18.6	17.2	20.0
Ave.	15.7	17.8	10.6	9 7	18.3	17.0	19.7
	Succulometer (ml. per 100 gms.)						
	1948		1949				
Treatment			1st harvest		2nd harvest		
	Raw	Canned 6 mo.	Raw	Canned 6 mo.	Raw	Canned 6 mo.	Canned 21 mo.
—N	17.0	17.0	27.0	25 0	18.5	17.3	16.5
+N	19.0	17.5	28.0	26.2	22.5	21.3	20.5
++N	21.0	19.0	27.0	25.5	22.0	20.6	14.0
—P	20.0	18.0	28.0	26.3	22.5	20.9	20.0
+P	16.0	16.0	27.5	25.2	17.5	16.7	16.5
—K	19.5	18.5	29.0	26.1	23.0	21.8	22.0
+K	20.5	19.0	27.5	25 5	24.0	22.7	16.0
++K	21 5	19.0	29.0	26.3	22.0	21.0	18.0
Ave.	19.3	18 0	27 9	25 8	21.5	20.3	17.9

TABLE 16.—Refractive Indices and Ascorbic Acid Contents of Sweet Corn Grown at Marietta, O. 1948 and 1949

Treatment and Lot No.	Refractive Indices			Ascorbic Acid (mg/100 gms.)					Total Sugars (Percent)				
	1949—2nd Harvest			1948		1949			1948		1949		
	Raw	Canned 6 mo.	Canned 21 mo.	Raw	Canned 6 mo.	Raw	Canned 6 mo.	Canned 21 mo.	Raw	Canned 6 mo.	Raw	Canned 6 mo.	Canned 21 mo.
—N (6)	1.3440	1.3418	1 3453	8.4	7.3	5.3	1.6	0.5	3.2	2.2	3.2	2.2	1.4
+N (3)	1.3460	1.3428	1.3451	9.3	5.4	8.5	5.8	0.0	3.0	1.8	3.0	2.1	1.2
++N (35) (2)	1.3454	1.3419	1.3420	8.5	6.5	7.5	4.4	0.0	2.7	2.1	3.0	2.0	1.0
—P (31) (32)	1.3451	1.3416	1.3410	7.6	5.5	7.4	3.5	0.0	3 2	1.7	3.0	1 9	1.1
+P (23) (34)	1.3463	1.3425	1.3420	9.3	6.7	8.5	4.7	0.0	3.6	1.9	3.1	2 0	1.2
—K (11)	1.3428	1.3408	1.3400	9.5	9.0	5.1	2.2	0.0	3.1	2.2	3.2	2.2	.9
+K (12)	1.3440	1.3413	1.3425	8.4	7.8	5.7	4.1	0.0	3.3	2.0	3.0	2.0	1.4
++K (9)	1.3451	1 3417	1.3412	8.2	6.8	6.3	2.6	0.0	3.0	2.0	3 0	2.0	1.1
Average	1 3448	1.3418	1.3424	8.7	6.9	6.8	3.6	.1	3.1	2.0	3.1	2 1	1.2

TABLE 17.—Average Weight of Head, Ascorbic Acid and Sugar Contents of Cabbage and Kraut from Cabbage Grown on Fertility Plots at Marietta, O. 1948 and 1949

Plot treatment†	Ave. weight head—lbs.		Ascorbic Acid (mg/100 gms.)				Total Sugars				Reducing Sugars				Non-reducing Sugars			
	1948	1949	1948		1949		1948		1949		1948		1949		1948		1949	
			Raw	Kraut*	Raw	Kraut	Raw	Kraut	Raw	Kraut	Raw	Kraut	Raw	Kraut	Raw	Kraut	Raw	Kraut
—N (6)	1.74	1.98	41.8	12.5	28.6	12.6	1.79	.51	3.49	.55	.64	.47	.70	.54	3.15	.04	2.79	01
+N (3 or 5)	5.33	2.71	41.8	7.8	26.6	12.0	3.42	.40	3.46	.52	.23	.41	.69	.48	3.19	.09	2.78	.04
++N (35-2)	4.64	5.56	41.2	9.0	22.3	8.7	3.79	.58	3.34	.57	.67	.49	.64	.53	3.12	.09	2.70	.03
—P (31-29)	2.33	3.67	41.4	6.1	22.5	12.4	3.27	.32	3.12	.56	.37	.30	.63	.49	2.70	.01	2.49	.07
+P (23-34)	2.33	3.77	41.6	7.2	29.1	12.6	3.44	.45	3.30	.50	.57	.44	.65	.49	3.07	.01	2.65	.01
—K (11)	2.94	3.21	41.4	5.3	24.2	13.0	4.37	.82	3.70	.57	1.18	.80	.78	.51	3.19	.01	2.92	.05
+K (12)	3.54	4.05	41.5	10.3	28.2	11.7	4.00	.60	3.73	.55	.86	.59	.70	.46	3.17	.02	3.02	.09
++K (9)	4.54	4.18	41.3	10.6	27.8	13.0	3.51	.76	3.56	.54	.48	.75	.67	.46	3.03	.01	2.91	.09
Average	3.42	3.64	41.4	8.6	26.2	12.0	3.70	.56	3.46	.54	.62	.53	.68	.50	3.08	.04	2.78	.05

*After 6 months storage at room temperature.

†Figures in parentheses indicate plots from which the samples were secured.

TABLE 18.—The Ascorbic Acid, pH and Total Acid Content of Fresh Cabbage and Sauerkraut Processed in 1948 as Affected by Fertility and Canning

Plot treatment	Ascorbic Acid (mg/100 gms.)				Total Acidity (percent)			pH		
	Fresh	Bulk kraut	Kraut 6 mo.	Kraut 12 mo.	Bulk kraut	Kraut 6 mo.	Kraut 12 mo.	Bulk kraut	Kraut 6 mo.	Kraut 12 mo.
—N	41.8	29.5	12.5	15.1	1.90	1.29	1.18	3.63	3.70	3.78
+N	41.1	23.6	7.8	17.0	1.56	1.07	1.08	3.77	3.85	3.79
++N	41.2	22.3	9.0	16.6	1.93	1.29	1.21	3.55	3.85	3.84
—P	41.4	23.6	6.1	10.8	1.31	1.03	1.08	4.05	3.97	3.98
+P	41.6	19.7	7.2	7.1	1.60	1.19	1.17	3.79	3.89	3.77
—K	41.4	20.5	5.3	17.0	1.98	1.35	1.24	3.50	3.80	3.82
+K	41.5	20.2	10.3	9.6	1.92	1.30	1.23	3.58	3.88	3.78
++K	41.3	19.5	10.6	17.9	1.81	1.20	1.25	3.72	3.88	3.76
Average	41.4	22.4	8.6	13.9	1.75	1.22	1.18	3.70	3.85	3.82

only 22.3 mg/100 gm. Because of the higher yield of cabbage, however, the per acre yield of ascorbic acid was almost twice as large with plants on the plot receiving the high nitrogen level as with plants on the plot receiving the low nitrogen level.

It is obvious from the data that fertility levels do affect the ascorbic acid content of cabbage. There are two possible explanations for the apparent effect on cabbage and not on sweet corn. In the first place the cabbage yield differences were far greater thus accentuating differences which may be attributable to factors which influence yield and ascorbic acid contents. In the second place the ascorbic acid content of cabbage (a leafy product) is much greater than sweet corn (a fruit) so that differences can be more clearly distinguished.

DISCUSSION AND CONCLUSIONS

EFFECTS OF SEASON

It is generally agreed that location and season, i. e., environmental factors greatly influence the composition of vegetables (see reference 9 for further reviews and summary). The data in this bulletin substantiate this statement.

Tomatoes grown in the greenhouse during the spring when the duration of the sunlight was longer, were higher in ascorbic acid, higher in total solids as indicated by refractive indices, and had a more desirable red color as evaluated visually and by the Hunter instrument than tomatoes grown during the fall when the intensity as well as the duration of the sunlight periods were reduced.

Seasonal variations affect the ascorbic acid contents of cabbage to a greater extent than fertility levels (see Table 17). For example, the average ascorbic acid content of cabbage from all lots was 41.4 mg/100 gm. in 1948 and only 26.2 mg/100 gm. in 1949. This difference of 15.2 mg/100 gm. is considerably greater than the 6.3 mg/100 gm. difference between the ascorbic acid content of the cabbage grown on the low and high nitrogen plots.

The differences in quality in sweet corn as evaluated by AIS and the Succulometer are greater between harvest dates for the 1949 season than for the corn harvested in 1948 and 1949 at what was assumed to be in an ideal stage for canning whole kernel sweet corn. (See Table 15). Sweet corn reaches a maximum of quality sometime during any particular season. The problem is to harvest it at this particular period.

For example, the AIS values for the 1948 and for the second harvest in 1949 averaged 15.7 and 18.3 respectively though the values for the first and second harvests for 1949 were 10.6 and 18.3 thus showing the large differences between harvest dates. Succulometer values (see Table 15) show equally great differences. Here the immature crop, i. e., first harvest in 1949 had a high average succulence of 27.9 ml/100 gm. compared to 19.3 ml/100 gm. in 1948 and 21.5ml/100 gm. in 1949 for corn harvested at what was considered the optimum stage of maturity for canning.

EFFECTS OF FERTILITY LEVELS

The literature on the effects of fertility levels on the quality of tomatoes, cabbage and sweet corn is often contradictory and the effects are usually shown to be slight even though there may be considerable differences in yield. The data presented in this bulletin support this general statement. For example, no definite differences in quality as determined in the research could be traced to fertility levels in sweet corn even though a difference in yield of 1624 lbs. was secured between the low nitrogen (plot 6) and the medium nitrogen (lot 3) in 1949. However, since the data relative to the effects of fertility levels (see Table 2) do not show any definite trends it is not surprising that a correlation between fertility level and quality could not be detected.

The cabbage data on the other hand show definite decreases in ascorbic acid in terms of mg/100 gm. as the yields increase due to larger applications of nitrogen. Thus the ascorbic acid value of cabbage grown on Plot 6 (i. e., low nitrogen plot) which yielded 16,220 pounds of cabbage per acre was 28.6 mg/100 gm. in 1949 as compared to 22.3 mg/100 gm. in Plot 2 which yielded 38,520 pounds of cabbage.

On the other hand the ascorbic acid contents of cabbage grown in 1949 on the low potash plot (11) was only 24.2 mg/100 gm. as compared to 28.2 and 27.8 mg/100 gm. on Plots 12 and 9 which were supplied with greater amounts of potash. The yields in pounds per acre were 35,040 (Plot 11), 39,960 (Plot 12), and 45,440 (Plot 9). Thus, both yields and ascorbic acid contents increased as the potassium level in the soil was raised. It should be noted, however, that these trends were not observed in 1948.

The tomato data show beyond a doubt that fertility levels do have an effect on quality as measured by ascorbic acid contents. In this instance the crops were grown under glass where several growth factors could be controlled most of the time. Adequate moisture was supplied at all times. Temperatures were never allowed to become unduly low but rather were high during the end of the growth of the spring crops. Light was doubtless a limiting factor during the fall in all three seasons. It is interesting to note, however, that in spite of limited light there were significant decreases in ascorbic acid brought about by increasing increments of nitrogen and phosphorus and increases in ascorbic acid brought about by increasing increments of potassium. Significant data were secured from several pickings of two fall and three spring crops (see Tables 3, 4 and 7). There were no exceptions to the trends indicated.

The yields in these instances were vastly reduced with plants on the plots maintained at the very low levels of nitrogen, phosphorus and potassium. Starvation symptoms were visible almost from the start of the crop and although no yield records were taken, it is doubtful if as much as 2000 lbs. per acre were harvested from any one of these three plots.

It is believed that much of the controversial statements in the literature relative to the effects of fertilizer levels can be explained by the small differences in yields between plants in various plots. The data presented herein prove that fertility levels do affect the vitamin contents of tomatoes when the yields are greatly reduced because of the lack of either one of the so-called major fertilizing elements, nitrogen, phosphorus or potassium.

This extends our knowledge of the effects of fertility levels presented in previous publications (1), (3), and (7). The increase in ascorbic acid contents noted with kale and other leafy vegetables during the spring season parallels the increase found in tomatoes as reported in this bulletin. However, in leafy vegetables the plants starving for potassium, magnesium and calcium all developed more vitamin C in terms of mg/100 gm. of fresh weight. This agrees with the results in this publication insofar as nitrogen and phosphorus are concerned. However, the ascorbic acid content of tomatoes increased with increased levels of potassium though in the case of leafy vegetables (chard and kale) as previously reported, the ascorbic acid content was increased by decreased levels of potassium. If, however, starvation symptoms progressed so that tissue became distinctly yellowed, the ascorbic acid content decreased. Here again it is well to remember that although the vitamin C content in mg/100 gm. fresh weight was higher in the kale and chard starving for potassium, magnesium and calcium, the yield per acre would be greatly lowered on the areas supplying low levels of these minerals because of reduced yields.

Carotene contents of the sweet corn, tomatoes and cabbage were not determined as in the work with green leafy vegetables largely because of the relatively low values compared to leafy vegetables. In summarizing the effect of fertility levels on chard and kale it was said that "It is relatively easy to predict the carotene content of leafy vegetables by the color of the leaves. Thin, dark green colored leaves usually contain more than thick leaves of similar shade." In this instance, any fertilizer treatment or lack of treatment which resulted in yellowed leaves also brought about a reduction of carotene. In this instance, the per acre yield of carotene was also reduced because of the attending reduced yields of the vegetation.

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